

June 24th 2008, A. Pany

### **Best strategy for PPP KF (revised)**

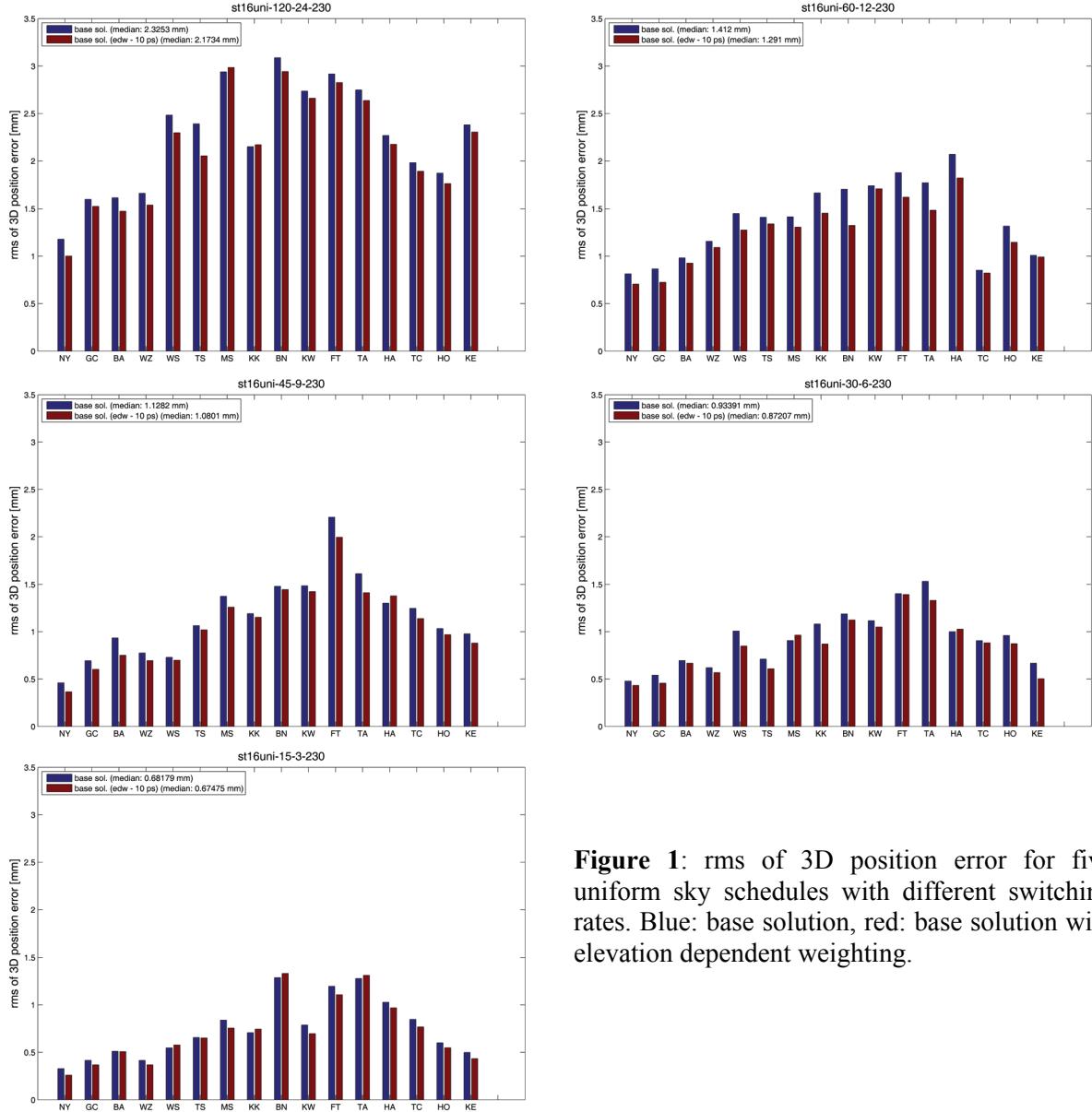
The PPP KF standard solution estimates a random walk zenith wet delay (variance rate: 0.7 ps<sup>2</sup>/s) with superimposed random walk gradients (variance rate: 0.5 ps<sup>2</sup>/s). These constraints were determined using schedule stat16\_12\_3p5\_D0ln (same constraints for all stations) and fit the values used for the OCCAM VLBI2010 simulations (for inter-software comparisons). These constraints were fixed for the base solution and were used for all PPP KF simulations until now.

The “best strategy” for PPP KF was determined using st16uni\_60\_12\_230. This schedule has less observation density than the stat16\_12\_3p5\_D0ln. Strategies tested were standard solution, standard solution with elevation dependent weighting, spherical harmonics and spherical harmonics with elevation dependent weighting. The variance rates for the standard solution were kept fix, the variance rates for the spherical harmonics were varied to find out the “best” values. For this specific schedule and using these variance rates it was found that i) applying elevation dependent weighting yields better results (for both models), and ii) spherical harmonics with variance rates of 0.01 ps<sup>2</sup>/s yield better results than the standard solution (see memo “Comparison of analysis strategies” of February 18<sup>th</sup> 2008).

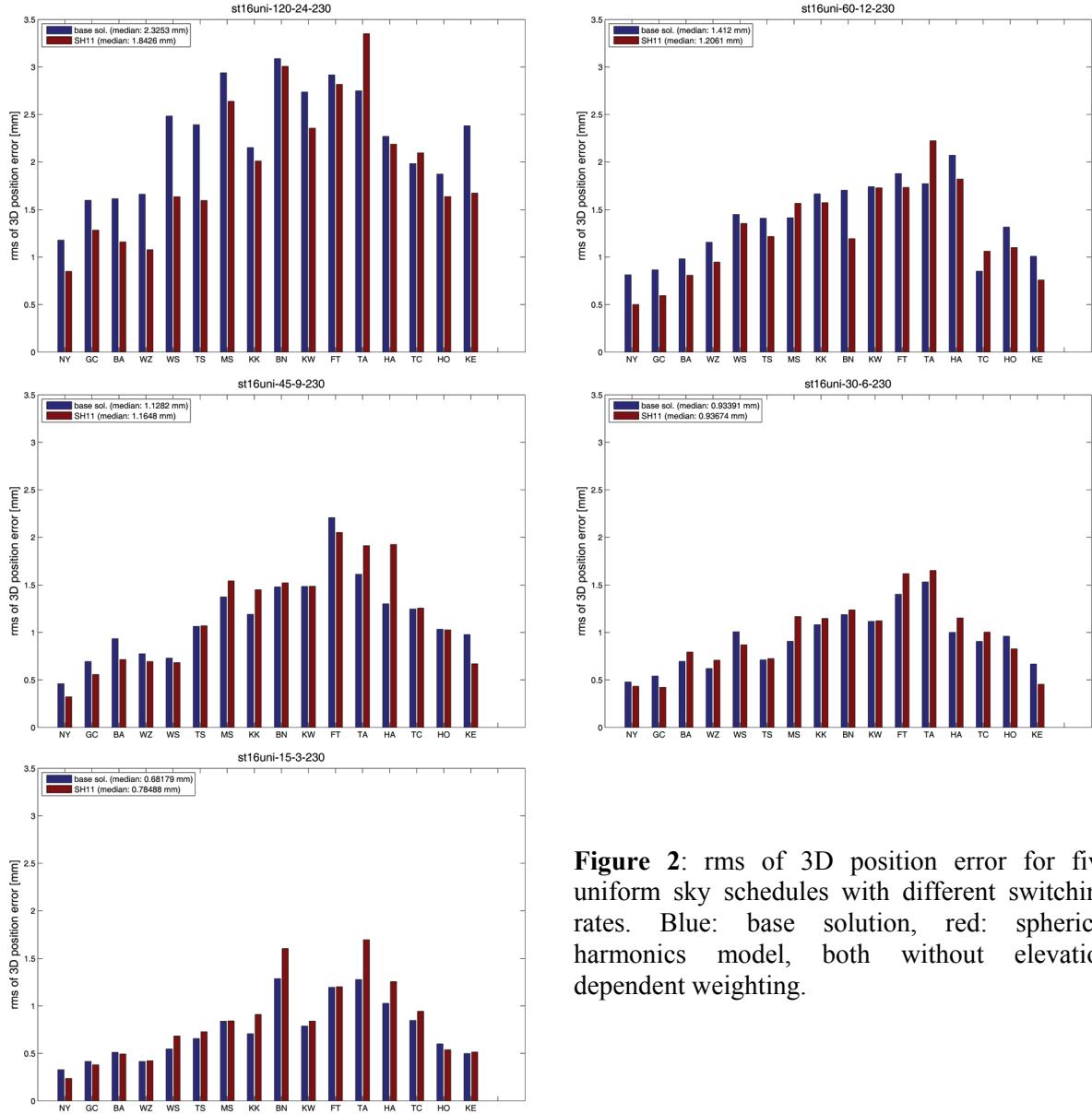
What I did do now was to run this comparison also for schedules st16uni\_120\_24\_230, st16uni\_45\_9\_230, st16uni\_30\_6\_230, and st16uni\_15\_3\_230, using the variance rates given above. Results can be seen in Figures 1 and 2. In these plots the stations are sorted by latitude (North to South).

Figure 1 shows comparisons of standard solution and standard solution with elevation dependent weighting for all five uniform sky schedules. It can be seen that there is a small improvement for all schedules and almost all stations. The few exceptions are rather wet stations. Since for these comparisons only 25 repetitions were used, it is possible that for wet stations pseudo-systematics are introduced by the multiplication with random numbers in the generation of turbulent equivalent zenith wet delay time series.

The situation is different in Figure 2 which shows a comparison of standard solution and spherical harmonics model (both without elevation dependent weighting). Two phenomena can be observed: i) there is a difference between wet stations and dry stations (there is a clear improvement for dry stations while for wet stations the improvement is not significant), and ii) there is a dependence on observation density (there is a significant improvement with the spherical harmonics model for the schedule with a switching rate of 120 s but the improvement becomes less and less significant for shorter switching times).



**Figure 1:** rms of 3D position error for five uniform sky schedules with different switching rates. Blue: base solution, red: base solution with elevation dependent weighting.



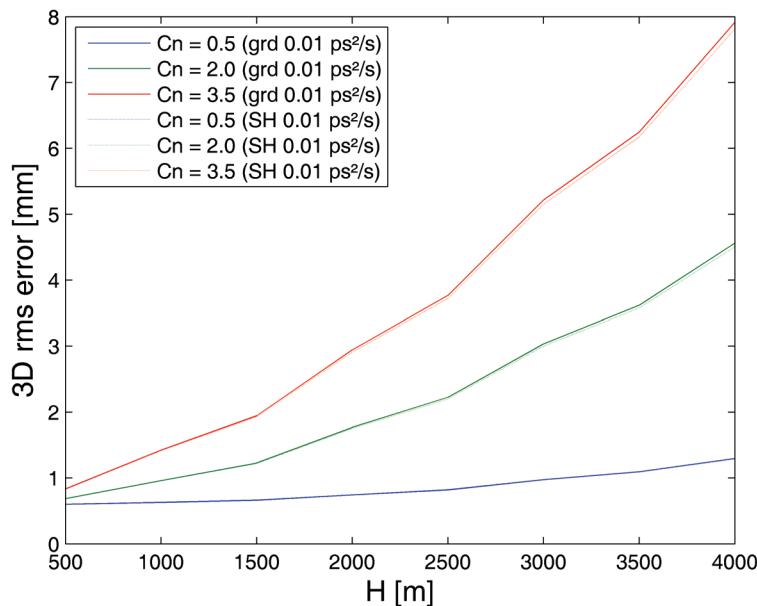
**Figure 2:** rms of 3D position error for five uniform sky schedules with different switching rates. Blue: base solution, red: spherical harmonics model, both without elevation dependent weighting.

Standard solution and spherical harmonics were never ran with the same variance rates, though. Thus, some additional simulation studies were performed:

- Standard solution and spherical harmonics were ran with the same variance rates to find out, whether the differences in Figure 2 are only due to using different variance rates or also due to using different models.
- The simulations were not run for VLBI2010 test schedules, but for the simulated time series I used for the investigation on the impact of turbulence parameters (see “On the impact of turbulence parameters and the scatter in 3D rms error caused by multiplication with random numbers in generation of fake delay observables“, June 17, 2008) to see, whether and how the “best” model and/or variance rates depend on atmospheric conditions and observation density.

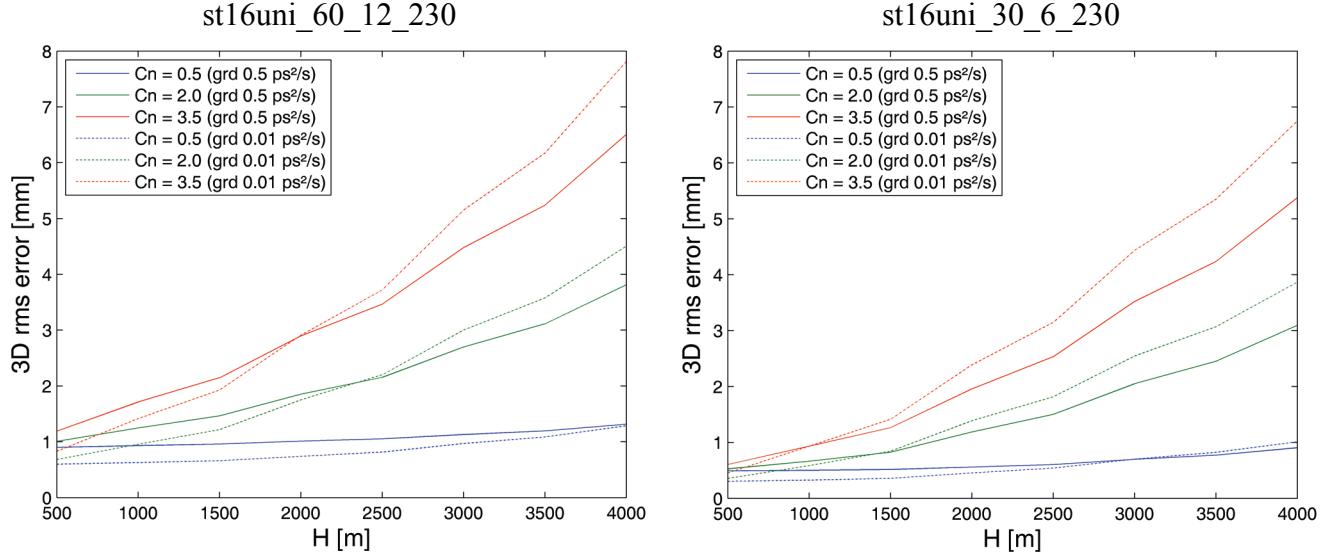
The fake delay time series were generated using different combinations of refractive index structure constants and effective heights of wet troposphere. Station WZ was used as reference station, i.e. time epochs, azimuths and elevations of observations were taken from this station. Simulations were performed for schedules st16uni\_60\_12\_230 and st16uni\_30\_6\_230.

Figure 3 shows rms of 3D position error versus effective height  $H$  of wet troposphere for three different  $C_n$  values (for schedule st16uni\_60\_12\_230) and compares the spherical harmonics model with the gradient model using the same variance rates (zwd 0.7 ps<sup>2</sup>/s, grd/SH 0.01 ps<sup>2</sup>/s). It can be seen that there is no significant difference between these two models when using the same variance rates. Differences observed before were thus due to the fact that the standard variance rates were used for the standard solution while the variance rates for the spherical harmonics model were “optimized” empirically (for this specific schedule).



**Figure 3:** rms of 3D position error versus effective height  $H$  of wet troposphere for refractive index structure constants  $C_n$  of 0.5, 2.0 and 3.5 [1e-7 m<sup>-1/3</sup>]. Wind speed was 7 m/s towards North-East. Solid lines show results for the standard gradient model (random walk zwd with 0.7 ps<sup>2</sup>/s, random walk gradients with 0.5 ps<sup>2</sup>/s). Dotted lines show results for the spherical harmonics model (random walk zenith wet delay with 0.7 ps<sup>2</sup>/s, random walk spherical harmonics with 0.01 ps<sup>2</sup>/s).

Figure 4 left shows rms of 3D position error versus  $H$  for three different  $C_n$  values for schedule st16uni\_60\_12\_230. Solid lines show results for the standard gradient model with variance rates of 0.5 ps<sup>2</sup>/s for the gradients (i.e. standard variance rates), dotted lines show results for the gradient model with variance rates of 0.01 ps<sup>2</sup>/s for the gradients. It can be seen that the smaller variance rates yield better results for smaller  $C_n$  and  $H$  values and that the larger variance rates yield better results for larger  $C_n$  and  $H$  values. This conclusion also holds for the results of schedule st16uni\_30\_6\_230 (Figure 4 right) but for this schedule the variance rates of 0.5 ps<sup>2</sup>/s yield better results than the smaller variance rates already for smaller effective heights than for the schedule with a 60 s switching rate.



**Figure 4:** rms of 3D position error versus effective height  $H$  of wet troposphere for refractive index structure constants  $C_n$  of 0.5, 2.0 and 3.5 [ $1e-7 \text{ m}^{-1/3}$ ]. Wind speed was 7 m/s towards North-East. Solid lines show results for the standard gradient model (random walk zwd with  $0.7 \text{ ps}^2/\text{s}$ , random walk gradients with  $0.5 \text{ ps}^2/\text{s}$ ). Dotted lines show results for the gradient model with variance rates of  $0.01 \text{ ps}^2/\text{s}$  for the gradients. The plot on the left shows results for schedule st16uni\_60\_12\_230, the plot on the right for schedule st16uni\_30\_6\_230.

Summing up it can be concluded:

- Elevation dependent weighting improves rms of 3D position error slightly.
- There is no improvement when using the spherical harmonics model instead of the gradient model in the PPP Kalman Filter (when estimating both as random walks). Differences observed before were due to using different variance rates. This might be different for the PPP LS, though.
- The best choice of variance rates for PPP KF is dependent on atmospheric conditions.
- The best choice of variance rates for PPP KF is dependent on observation density.